



**CHESAPEAKE BAY FOUNDATION**  
*Saving a National Treasure*

**REPORTS**



## **Angling for Healthier Rivers**

The Link Between Smallmouth Bass Mortality and Disease  
and the Need to Reduce Water Pollution in Chesapeake Bay Tributaries

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**April 2013**



## CHESAPEAKE BAY FOUNDATION

*Saving a National Treasure*

### PRESIDENT'S MESSAGE

Loren Anne Barnett/CBF Staff



*William C. Baker, President,  
Chesapeake Bay Foundation*

When it comes right down to it, most of us are environmentally conscious because of the impact pollution and habitat degradation have on fish, birds, and all variety of wildlife. As we know, each living creature is connected to each other and ultimately to us.

This report is about one of the great sport fish in the fresh water reaches of the Bay watershed—smallmouth bass. They are an economic engine and a keystone species, prized for the pure enjoyment of hooking into one, but also as an indication of a system that is working. Or not.

When smallmouth are diseased, weakened, or otherwise stressed, we know things aren't right. From the mighty Shenandoah River, which drains the western sections of Virginia's Bay watershed, to the enormous reach of the Susquehanna all the way to Cooperstown, New York, the range of the smallmouth bass is a testament to all

that the Bay's rivers have to offer and to the rivers' impact on the Chesapeake.

As Tom Pelton chronicles in this seminal report, the worrisome plight of smallmouth bass foretells broader problems downstream if left uncorrected. The good news, however, is that science is beginning to give us answers. We know what needs to be done, and the solutions have broad-ranging benefits.

From healthy drinking water to streams that are safe for our kids to swim, addressing pollution, reducing habitat loss, and restoring natural filters is a prescription for getting the job done. Read the report, get involved, contact your elected officials, and make a difference. Individually, we sometimes feel unable to be heard. But collectively, our voices are deafening.

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William C. Baker  
President

# Angling for Healthier Rivers

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COVER PHOTO: This smallmouth bass was caught in the Susquehanna River in Pennsylvania. A large lesion exemplifies the illnesses this popular sport fish too often suffers. Credit: J. Raymond/Pennsylvania Fish and Boat Commission

## CHESAPEAKE BAY TRIBUTARIES WHERE SMALLMOUTH BASS HAVE SUFFERED FISH KILLS, DISEASE, AND SEXUAL ABNORMALITIES



Smallmouth bass live in many rivers and streams. Above in red are waterways in the Chesapeake Bay region where the fish have suffered fish kills, disease, and sexual abnormalities over the last decade.

# Angling for Healthier Rivers

## The Link Between Smallmouth Bass Mortality and Disease and the Need to Reduce Water Pollution in Chesapeake Bay Tributaries

### EXECUTIVE SUMMARY

The thousands of rivers and streams in six states and the District of Columbia that drain into the Chesapeake Bay are like the complex network of arteries and capillaries that nourish a living body. When the Chesapeake's tributaries are troubled, the Bay suffers too. A ripple effect spreads throughout the ecology and economy of the entire 64,000-square-mile Chesapeake Bay watershed.

Over the last decade, one of the most prized freshwater sport-fish species—smallmouth bass—has suffered fish kills and perplexing illnesses in several Bay tributaries. These tributary rivers include the South Branch of the Potomac River in West Virginia, the Shenandoah and Cowpasture Rivers in Virginia, the Monocacy River in Maryland, and the Susquehanna River in Pennsylvania.<sup>1</sup> Problems with the fish have included lesions, blotchy skin, wart-like growths, excessive mucus covering their bodies, lethargic behavior, and abnormal sexual development in which males grow eggs in their testes.<sup>2</sup> In the Susquehanna River, smallmouth bass populations have plummeted, with catch rates of adults falling 80 percent between 2001 and 2005 in some areas.<sup>3</sup> According to the Pennsylvania Fish and Boat Commission, the population has not recovered. In 2012, this dramatic decline prompted the state agency to impose emergency regulations that prohibit fishing for the species in much of the river from May 1 to June 15.<sup>4</sup> This ban in the Susquehanna River—the largest source of fresh water to the Chesapeake Bay—will continue in 2013.

Smallmouth bass do not tolerate pollution well.<sup>5</sup> Thus, they are an indicator of water quality. While the specific causes of the deaths and illnesses among smallmouth bass remain unclear,<sup>6</sup> leading fisheries biologists studying the problem believe that a “perfect storm”<sup>7</sup> of contributing factors has overwhelmed a sensitive species. In fact, some suggest that smallmouth bass may be like a “canary in the coal mine,”<sup>8</sup> indicating possible future health problems with other species of fish. High levels of nitrogen and phosphorus pollution, rising water temperatures, and chemical contaminants may have combined to weaken the immune systems of smallmouth bass and make them more susceptible to naturally occurring bacteria, viruses, and parasites.<sup>9</sup>

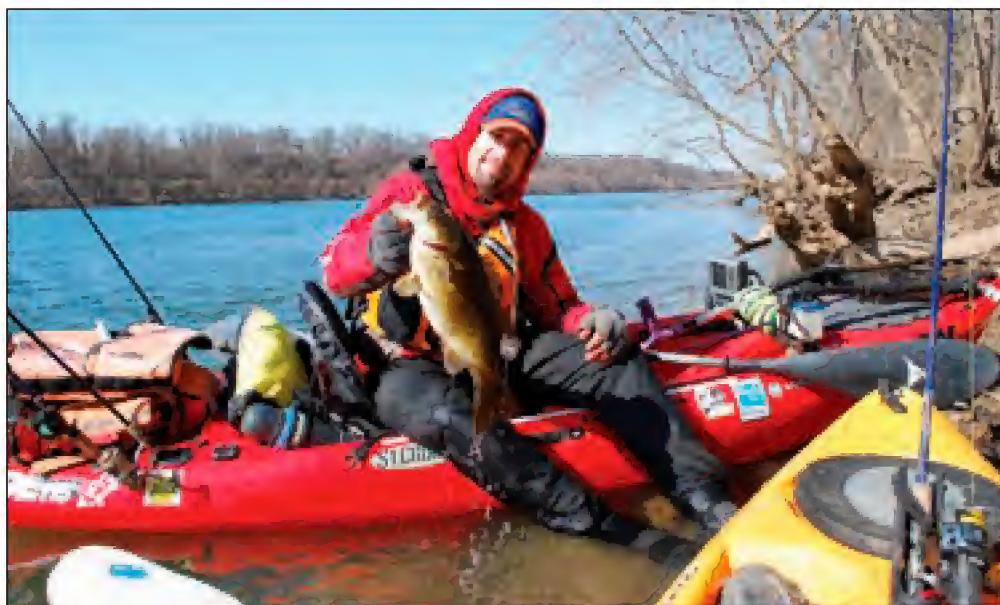


A. Shieh/Pennsylvania Fish and Boat Commission

*Nitrogen and phosphorus pollution contribute to a “perfect storm” of problems that are killing smallmouth bass. This smallmouth bass, caught in Pennsylvania, suffered from gill erosion.*

The Chesapeake Bay Foundation (CBF) compiled this report by interviewing five leading smallmouth bass experts<sup>10</sup> and examining peer-reviewed journal articles, as well as reports from federal and state agencies. Some conclusions include:

- Fishing for the species is responsible for \$630 million annually in sales in Pennsylvania, Maryland, Virginia, and West Virginia, the four Bay states where fish kills and diseases have occurred. Sales of boats, fishing rods, and more contribute to that figure. Additionally, smallmouth bass are responsible for \$193 million annually in salaries and wages for about 5,700 people employed in fishing-related jobs and \$41 million in state and local tax revenues.<sup>11</sup>
- Phosphorus and nitrogen pollution levels are high in many of the river segments where fish have died or become sick. In the Susquehanna River and tributaries, average phosphorus pollution levels in 12 of 24 sites monitored by the U.S. Geological Survey between 2007 and 2011 were among the worst in the Chesapeake Bay watershed.<sup>12</sup> And 11 of these 24 sites had total nitrogen pollution levels that were among the worst in the region. (“Worst” is defined as ranking in the top third for levels of these pollutants among 65 sites studied in the Bay watershed). Some monitoring sites along the Monocacy River and the Potomac River and its tributaries also registered high levels of these pollutants.<sup>13</sup>
- Scientists believe that nitrogen and phosphorus pollution may be contributing to fish deaths and diseases in two ways. The first is by spurring the growth of parasites (myxozoans and trematoids) and their hosts (worms and snails).<sup>14</sup> The second is by feeding algal blooms that raise pH levels and lower oxygen concentrations,<sup>15</sup> stressing young smallmouth bass.



*Smallmouth bass fishing is worth an estimated \$630 million a year in the four Chesapeake Bay region states where fish kills have occurred over the last decade. In this photo, veteran smallmouth bass fishing guide Jeff Little holds a smallmouth bass in the Susquehanna River, much of which will be closed to smallmouth fishing this spring (2013).*



R. Bane/Pennsylvania Fish and Boat Commission

*Blotchy skin (melanosis) is present on this smallmouth bass caught in the Susquehanna River.*

- Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey, and colleagues recently identified a type of parasite (*Myxobolus inornatus*) in juvenile smallmouth bass that have been dying in the Susquehanna River.<sup>16</sup> This parasite is similar to one that causes a deadly disease in trout. The parasite's possible host (a bottom-dwelling worm) may be encouraged by nitrogen and phosphorus pollution.<sup>17</sup>

While more study into the causes of the fish kills and illnesses is required, one fact is clear. To restore populations of smallmouth bass, as well as the health of the Chesapeake Bay and its rivers and streams, we must reduce nitrogen and phosphorus pollution. Of the myriad of contributing factors, this is one factor that people can easily control. And addressing the problem will help sustain the economic benefits of smallmouth bass.

Cutting back nitrogen and phosphorus pollution will help reduce stress on smallmouth bass and other fish. Reducing pollution will also further efforts the Bay states—New York, Pennsylvania, Maryland, Delaware, Virginia, and West Virginia—and the District of Columbia are making to meet mandatory limits on pollution entering the Chesapeake Bay. In 2010, EPA established science-based limits for nitrogen, phosphorus, and sediment pollution and allocated reduction targets to each state. The states then developed and now are beginning to put into effect plans that should restore clean water sufficiently to remove the Bay from the notorious Clean Water Act ‘dirty waters’ list (of section 303[d] of the act). The plans must be in place by 2025. Together the limits and the states’ plans are the Clean Water Blueprint for the Chesapeake and its rivers and streams.

The Bay states are making good progress already. But the story of the smallmouth bass reminds us that the job is far from done. The good news is that as we accelerate implementation of the Blueprint, we can expect healthier fishing and swimming, the creation of thousands of jobs,<sup>18</sup> and a proud legacy of restoration for our children and grandchildren. Truly, we find ourselves at the moment in time for the Bay.

## KAYAK FISHING ON THE SUSQUEHANNA RIVER

It was a black and icy February morning when the anglers launched their kayaks onto the Susquehanna River.

Juan Veruete and Jeff Little, veteran fishing guides, were on a nearly mile-wide segment of the river near Harrisburg, Pennsylvania.

Out on the boulder-strewn waterway, the stars faded as the sky blushed in the east. Winds whipped up small waves, which reflected the light as the sun rose over leafless trees.

For nearly 10 hours, the friends paddled, exposed in the biting wind, atop flat plastic floats the size of surfboards. To protect themselves from hypothermia, they wore waterproof dry suits and layers of fleece.

They cast their rods with their right hands, as they maneuvered paddles with their left in a tricky game of fighting to stay pointed into the wind.

Why do they fish in such severe conditions? Veruete explained that he's been fishing since he was five years old—and can't keep himself off the river, even in winter.

"It's like an adrenaline junky kind of thing, you know? Except that this is good for you," Veruete said, laughing. "You come out, you get on the river, throw some baits, and you catch some huge smallmouth bass. It's a lot of fun."

Recently, however, fishing for smallmouth bass has become much harder on the Susquehanna—for everyone, year round. Catch rates of smallmouth bass have fallen by more than 80 percent as a mysterious disease has killed off many young fish, according to the Pennsylvania Fish and Boat Commission.

"About every guy that's been on the river for an extended period of time will say that they feel like they are catching fewer fish," Veruete said. "You know, we've got a great population of adult, smallmouth here. But we have very few [juvenile fish] coming up behind those smallmouth to fill in the gap."

From across the water, Little suddenly screamed. "Yeah! Whoohoo! Fish on! Fish on!"

"Already?" Veruete replied, paddling frantically toward his friend. "Is it a good one?"

After a fight with the fish, Little plucked a 20-inch-long smallmouth bass out of the water. It was shimmering greenish gold, with red eyes and a sun burst pattern on the side of its head.



Tom Pelton/CBF Staff

Juan Veruete (left) and Jeff Little fish on the Susquehanna River.

"These are just beautiful fish, beautiful fish," Veruete said, admiring the smallmouth before releasing it back into the river. "They are like little tanks that have the engine of a sports car in them. That's what I love about them."

Veruete and other devoted smallmouth bass anglers were forced to hang up their rods from May 1 to June 15 in 2012 because of the declining fish population. The Pennsylvania Fish and Boat Commission imposed emergency regulations that make it illegal to possess, or even try to catch, smallmouth bass in much of the Susquehanna River during the spring spawning season. This prohibition is meant to help the fish reproduce and recover their populations.

Little said that the troubling diseases in the fish strongly suggest a need to reduce pollution in the river.

"Biologically, there is something wrong with these fish, and that speaks to water quality," he said. "There are water-quality issues that really need to be addressed, and hopefully they will be."

Much of the Susquehanna River will once again be closed to smallmouth anglers this spring from May 1 to June 15. Left out in the cold will be people like Veruete and Little, whose lives and livelihoods are forever caught in the river's flow.

## DESCRIPTION AND HISTORY OF SMALLMOUTH BASS

Smallmouth bass are loved by anglers because they are spectacular fighters. When hooked, these bronze freshwater fish with red eyes and stripes tend to leap high out of the water and thrash with the power of fish several times their size.<sup>19</sup> Also called “bronzebacks,” they favor faster-moving, rocky, cooler, upstream sections of rivers, and so are often pursued by outdoors enthusiasts in waders, kayaks, canoes, and shallow-bottomed boats.

Smallmouth bass (*Micropterus dolomieu*) owe their name to the fact that their jaws are shorter than those of their larger cousins, the largemouth bass (*Micropterus salmoides*).<sup>20</sup> Mature “smallies” are often about 12 to 20 inches long and weigh up to about eight pounds.<sup>21</sup> In contrast to the horizontal stripes of largemouth bass, smallmouth bass have dark vertical stripes.<sup>22</sup>

Smallmouth bass eat crayfish, insect larvae, and other fish. They spawn in rocky areas of rivers during May and June. Males build nests out of sand and gravel, and females lay thousands of eggs. The male guards the nest from predators until the young fish hatch and are large enough to swim away.<sup>23</sup> Predators of smallmouth include walleye, kingfishers, eagles, osprey, and humans. Young smallmouth are preyed upon by older, larger smallmouth.

Fishing, however, is not believed to cause any significant declines in smallmouth bass populations because in recent years 98 percent<sup>24</sup> of anglers catch and release their smallmouth, a major increase over decades ago. Fishermen and women say they are taking greater care not to kill smallmouth because of a growing concern about conserving fish populations.<sup>25</sup>

Smallmouth bass are not native to the Chesapeake Bay region; they are originally from the Mississippi River basin and Great Lakes. During the 19th century, the fish were stocked in rivers across the U.S., often by federal and state fish commissions, because smallmouth were regarded as a desirable game species.<sup>26</sup> In 1854, 20 smallmouth bass were carried from the Ohio River in the water tank of a train and released into the Chesapeake & Ohio Canal, where they multiplied and spread into the Potomac and connecting rivers.<sup>27</sup> Smallmouth were introduced to the Susquehanna River in 1869, the James River in 1871, and the Patuxent River in 1897.<sup>28</sup>



Tom Pelton/CBF Staff

*Smallmouth bass, also called “bronzebacks” or “smallies,” often have a bronze or brownish color and vertical stripes. The fish are native to the Mississippi River basin and Great Lakes, and were introduced to the Chesapeake Bay region starting in the 1850s.*



**John Mullican**  
Western Region, District II  
Manager, Inland Fisheries  
Division of the Maryland  
Department of Natural  
Resources

*"Smallmouth bass are extremely popular among anglers. But the bigger picture is, they are an indicator of the health of our rivers. When they have problems, it is a warning that things aren't quite right in our ecosystem."*

## ECONOMIC AND BIOLOGICAL SIGNIFICANCE

Despite their origins as outsiders, smallmouth bass have been enthusiastically embraced and are now a major part of the Chesapeake Bay region's culture and economy. (See specific economic impacts in Figure 1<sup>29</sup> below).

In 2005, a smallmouth bass fish kill in part of the Shenandoah River in Virginia interrupted fishing for 2,100 licensed anglers and caused an estimated \$700,000 in economic damage in one year.<sup>30</sup>

"It's a big business. A lot of people make a living from smallmouth bass," said Jack Cook, former President of the Potomac River Smallmouth Club, a conservation organization.<sup>31</sup> "Think of all of the stores that sell everything from boats, to fishing rods, equipment, and fishing licenses. It all adds up."

Beyond their economic and cultural role, some biologists believe smallmouth bass are important because they are sensitive to environmental conditions. Unlike species that are fished less often, smallmouth bass are monitored carefully by federal and state fisheries managers.

**FIGURE 1**  
**ANNUAL ECONOMIC IMPACT OF SMALLMOUTH BASS FISHING**  
**IN THE CHESAPEAKE REGION**



**TOTAL: \$630 million annually in sales; \$193 million in salaries and wages; about 5,700 jobs; and \$41 million in tax revenues.**

Sources: American Sportfishing Association; U.S. Fish and Wildlife Service. Note: Figures are from 2011 and take into account a multiplier or "ripple effect" in the economy.<sup>29</sup>

It is possible other fish species could also be suffering die-offs, but scientists might not know it because nobody has kept numbers on them.<sup>32</sup>

As a result, smallmouth can serve the role as a “canary in the coal mine,”<sup>33</sup> warning scientists of pollution problems that may eventually harm a variety of fish and animals.

“Smallmouth bass are extremely popular among anglers,” said John Mullican, Western Region, District II Manager, Inland Fisheries Division of the Maryland Department of Natural Resources.<sup>34</sup> “But the bigger picture is: Smallmouth bass are an indicator of the health of our rivers. When they have problems, it is a warning that things aren’t quite right in our ecosystem.”



**Jim Hedrick**  
District Fisheries  
Biologist for the  
West Virginia Department  
of Natural Resources

## CHRONOLOGY OF MORTALITY AND DISEASE

Scientists first observed the string of health problems with smallmouth bass in 2002 in the South Branch of the Potomac River in West Virginia (see map opposite page 1). Numerous smallmouth bass and fish of other species were reported dead, many with lesions.<sup>35</sup> The exact cause remains unknown.<sup>36</sup>

“There were fish dead for almost 80 miles—more than we could count, many thousands,” said Jim Hedrick, District Fisheries Biologist for the West Virginia Department of Natural Resources.<sup>37</sup> “Remember, this water eventually flows into the Chesapeake Bay. And so if something is toxic here, then ultimately it goes to the Bay.”

Chronic, low-level mortality of smallmouth bass continued in the South Branch of the Potomac River for the next several years, with another major fish kill in the spring of 2005.<sup>38</sup>

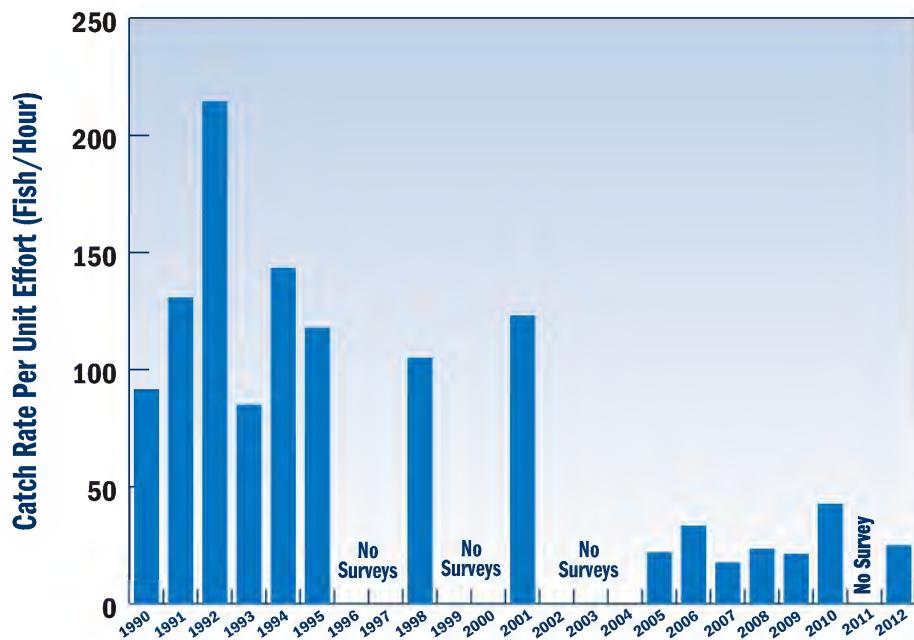
In 2004, deaths and lesions spread to smallmouth bass in another Potomac River tributary, the North Fork of the Shenandoah River in Virginia, hitting the entire length of the river.<sup>39</sup> The next year, fish died along 100 miles of the South Fork of the Shenandoah, and sporadically on the river’s main stem. Anglers and professional fishing guides estimated

*“There were fish dead for almost 80 miles—more than we could count, many thousands....Remember, this water eventually flows into the Chesapeake Bay. And if something is toxic here, then ultimately it goes to the Bay.”*

### FIGURE 2 TIMELINE OF SMALLMOUTH BASS FISH KILLS

- **2002** — Scientists observed thousands of fish dead in the **South Branch of the Potomac River**, many with lesions.
- **2003** — Deaths and lesions spread to smallmouth in the **North Fork of the Shenandoah**, another Potomac tributary.
- **2004** — Fish died along 100 miles of the **South Fork of the Shenandoah River**.
  - **2005** — Young smallmouth bass started dying off in the **Susquehanna River**, many with lesions.
- **2007** — Young smallmouth bass continue to die in the **Susquehanna River**.
- **2008** — Fish illness and death were reported in the **Cowpasture River**, a tributary to the James River.
- **2009** — A fish kill on the **Monocacy River** eliminated about 65 percent of the smallmouth bass.
- **2011** — Blotchy skin, open sores, and wart-like growths in adult fish in the **Susquehanna River** were reported.
- **2012** — Fishing for smallmouth bass from May 1 to June 15 was banned in much of the **Susquehanna River**.

**FIGURE 3**  
**CATCH RATE OF SMALLMOUTH BASS ON THE MIDDLE SUSQUEHANNA RIVER**  
**1990-2012**



Source: Pennsylvania Fish and Boat Commission. Note: Figures reflect numbers of adult fish caught per hour by researchers on the Susquehanna River from Sunbury to the York Haven Dam.

that up to 90 percent of the adult smallmouth were eliminated from parts of these rivers during those two years.<sup>40</sup> In 2007, 2008, and 2009, deaths of fish were also reported in the Cowpasture River, a tributary to the James River.<sup>41</sup>

Meanwhile, in May 2009, numerous dead smallmouth bass with lesions were reported in the Monocacy River, north of Frederick, Maryland.<sup>42</sup> Biologists who investigated estimated that the smallmouth populations in that river dropped 65 percent, and that 29 percent of the fish in the Monocacy had lesions on their skin.<sup>43</sup>

Some of the worst problems hit parts of the Susquehanna River in Pennsylvania. In 2005, *Bassmaster Magazine* listed the Susquehanna as one of the five best bass fishing rivers in America.<sup>44</sup> The same year, however, smallmouth bass younger than a year old began to die off.<sup>45</sup> Over the next several years, excessive mortality devastated several consecutive year classes of smallmouth bass, followed by reports of blotchy skin (melanosis), open sores, and wart-like growths in adult fish.<sup>46</sup> Catch rates of smallmouth bass in the middle Susquehanna River declined by more than 80 percent between 2001 and 2005, and they have not rebounded since, according to the Pennsylvania Fish and Boat Commission.<sup>47</sup>

“I truly am concerned that I’ll be the Director when the last bass is caught out of the river,” said John Arway, Executive Director of the Pennsylvania Fish and Boat Commission.<sup>48</sup> “I can only imagine what the Director felt like when the last blue pike was caught out of Lake Erie. I do not want to be in that position.”

This severe and long-lasting population decline—driven by deaths of young smallmouth bass—makes the situation in the Susquehanna River markedly worse than in the other



**John Arway**

Executive Director of the  
Pennsylvania Fish and  
Boat Commission

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## THE REBOUND OF SMALLMOUTH BASS IN THE SHENANDOAH RIVER

Early in his career, Jeff Kelble worked for a software training company. But he often found himself playing hooky, forwarding calls to his cell phone—in what he jokes was his real “office,” out on the river.

“The rivers in the Mid-Atlantic are, in my opinion, the best rivers in the world for smallmouth bass fishing,” Kelble said, as he rowed down the Shenandoah River on a recent afternoon, about an hour-and-a-half west of Washington, D.C.

Kelble picked up his rod and cast into the stunningly beautiful river, which flows through Virginia and West Virginia into the Potomac River. The water was green and smooth. The banks were lined with the white trunks of sycamores. And the sun was like a silvery quarter burning a halo in the overcast sky.

As he fished, he explained that he left the computer business to become a full-time fishing guide in 1998. He’s 41 years old now. But fishing has been the center of his identity since he was a child.

“I think I’ve made everybody in my life fish with me, including my wife and all my friends,” said Kelble, as he reeled in his line.

In 2003, he and his wife moved from suburban Washington to the tiny town of Boyce, Virginia, in the Shenandoah Valley to open up a bed and breakfast. The plan was to rent rooms to clients in his fishing-guide business.

But after back-breaking work renovating a century-old house to create the B & B, at just the time his wife, Erica, was pregnant—most of the smallmouth bass in the river suddenly died.

“In some parts of the river, I estimate we lost 90 percent of the fish,” Kelble said. “That was the end of fishing in the Shenandoah Valley for years.”

Kelble said he thought about selling their new home and moving away. But instead, he switched careers again, becoming a crusader for the river. He established a nonprofit organization called Shenandoah Riverkeeper. In this capacity, he now patrols the water, educates the community, and advocates for stronger government controls on pollution.

“I don’t use the word activist here...or environmentalist,” Kelble said, laughing. “But I started my career in conservation. And I really am a conservationist at heart, always have been.”



Tom Pelton/CBF Staff

Riverkeeper Jeff Kelble rowing on the Shenandoah River in Virginia.

For years, two chicken slaughter houses in the Shenandoah Valley released tons of waste into the river. Kelble filed a notice of intent to sue the owner of the plant that handled the waste. Kelble’s legal action prompted Virginia to force the plant to cut its nitrogen and phosphorus pollution by 95 percent, according to the Virginia Department of Environmental Quality.

The result has been an almost 100,000-pound annual reduction of these pollutants contaminating an important Chesapeake Bay tributary, according to state figures.

The smallmouth bass populations in the river rebounded, although the reasons are not clear. The increase may have been caused in part by favorable rain conditions in the spring that helped the survival of young fish, according to the Virginia Department of Game and Inland Fisheries.

“The population of adult smallmouth bass in the Shenandoah River right now, coming through 2012, is as good as it’s been in the last 15 years,” said Stephen J. Reeser, District Fisheries Biologist with the state agency.

Despite the reduction in pollution and the comeback of the fish, the river is still in trouble, in many ways. Large algal blooms, fed by nitrogen and phosphorus pollution from many sources, smother the river at times in the hot months. And many male smallmouth bass have unexplained sexual abnormalities.

“The things that are causing our male fish to grow eggs in their testes?” Kelble asked. “Think about it. This is the same water we are drinking.”

regional waterways, according to fisheries biologists who are studying the issue.<sup>49</sup> In the other rivers, adult smallmouth bass died more frequently than juveniles. In some cases the adult populations have since bounced back.

Numbers of adult smallmouth bass have rebounded in the South Branch of the Potomac River and in the Shenandoah River in Virginia, although not in the Susquehanna or Monocacy Rivers.<sup>50</sup> The population status in the Cowpasture River is unclear because of insufficient monitoring.<sup>51</sup>

### THEORIES ABOUT THE CAUSES OF FISH DISEASE AND MORTALITY

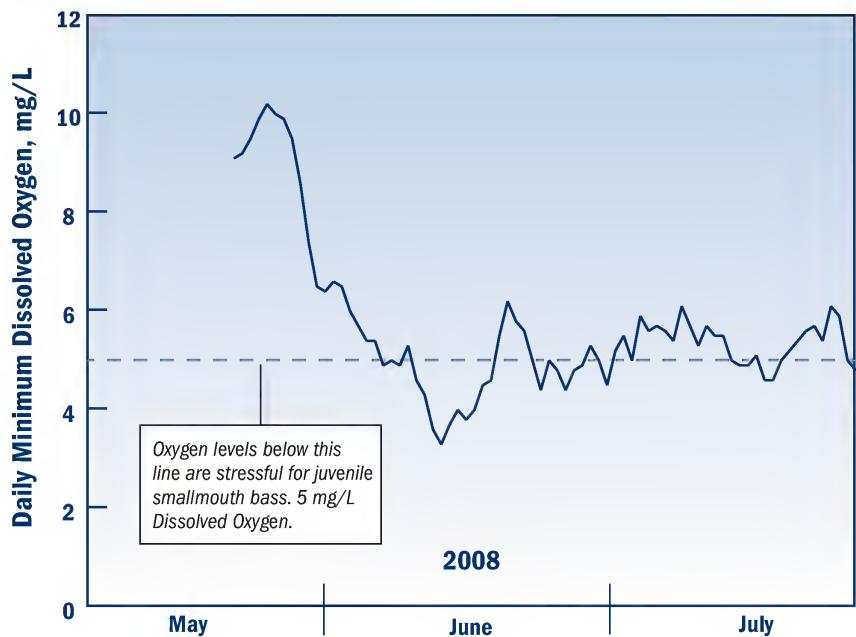
The leading theory of Dr. Vicki Blazer of the U.S. Geological Survey and her colleagues about the origin of the fish kills is that a combination of factors is stressing smallmouth bass and weakening their immune systems.<sup>52</sup> Those factors likely include algal blooms spurred by phosphorus and nitrogen pollution; rising water temperatures caused in part by climate change;<sup>53</sup> and endocrine-disrupting chemicals, such as herbicides, cosmetics, detergents, and hormones in animal and human waste. Together, they make smallmouth bass more vulnerable to infections from naturally occurring bacteria, such as *Aeromonas hydrophila* and *Flavobacterium columnare*.<sup>54</sup> In addition, scientists have occasionally observed a virus that normally infects largemouth bass (called the largemouth bass virus) in both living and dead smallmouth bass.<sup>55</sup> Researchers speculate that this virus could increase stress on the fish and further weaken their immune systems, making them more susceptible to bacteria and parasites in the river.<sup>56</sup>



Pennsylvania Fish and Boat Commission

*This algal bloom on the Susquehanna River was likely fed by phosphorus pollution.*

**FIGURE 4**  
**OXYGEN LEVELS IN SHALLOW PARTS OF THE SUSQUEHANNA RIVER**



Source: Pennsylvania Fish and Boat Commission. Note: Dissolved oxygen levels shown are for the Susquehanna River, at Clemson Island, near New Buffalo, Pennsylvania. The monitored area is a “microhabitat” or shallow part of the river where fish younger than one year congregate. (This data was the most recent available for shallow areas of the river.)

“It’s almost like you reach the perfect storm situation,” said Dr. Blazer.<sup>57</sup> “There have been stressors, and smallmouth bass have been able to overcome them or deal with them. But eventually, the fish get to a point where they cannot cope with them anymore.”

In the Susquehanna River, algal blooms—possibly fed by high levels of dissolved phosphorus<sup>58</sup>—appear to have created low-oxygen conditions at night in shallow alcoves of the waterway where young smallmouth bass congregate.<sup>59</sup> This appears to be severely decreasing the survival rates of juvenile fish in the Susquehanna, especially when combined with rising water temperatures<sup>60</sup> and low-flow conditions caused by reduced rainfall.<sup>61</sup> However, in other regional rivers, scientists have found no connection between die-offs of smallmouth bass and oxygen levels in the waterways.<sup>62</sup>

Beyond the “perfect storm” theory of weakened fish immune systems, scientists are also exploring some alternative ideas. In Virginia, scientists are looking into a species of bacteria (*Aeromonas salmonicida*) that can kill fish without the help of environmental stress.<sup>63</sup> Researchers in West Virginia are exploring whether toxic blooms of blue-green algae (*Cyanobacteria*) might have killed smallmouth bass, although they concede this is just a question worth pursuing without much evidence yet.<sup>64</sup>



**Dr. Vicki Blazer**  
Research Fisheries  
Biologist for the U.S.  
Geological Survey

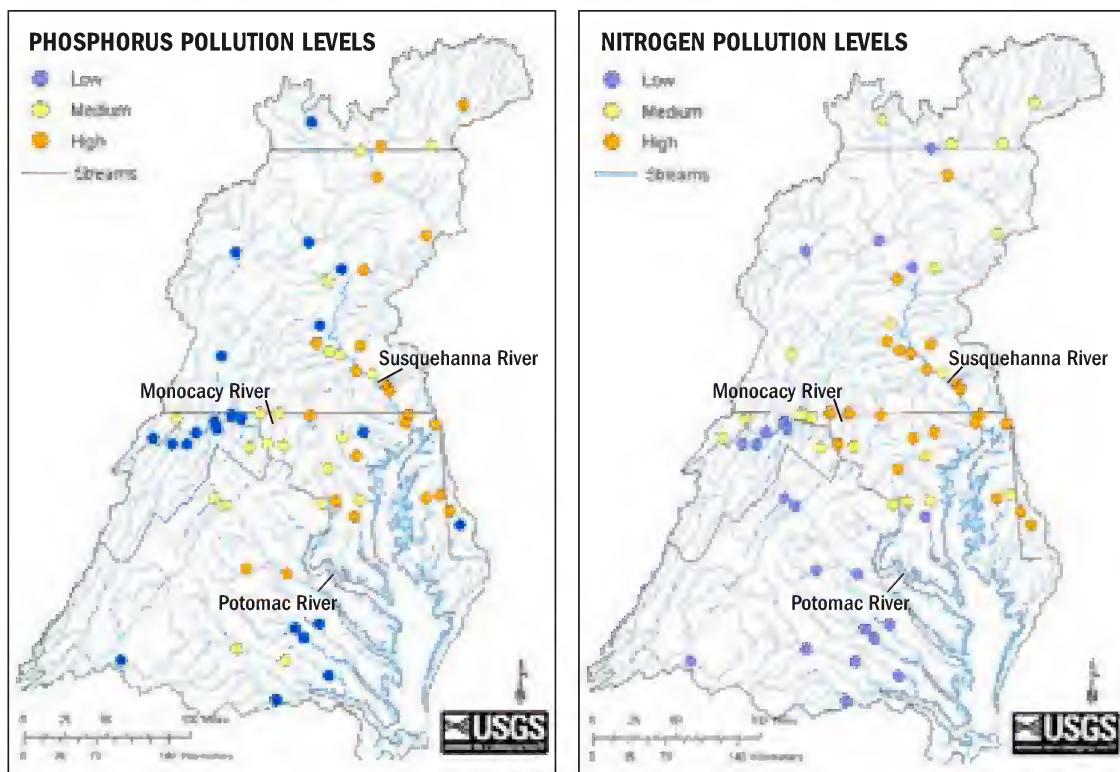
*“It’s almost like you reach the perfect storm situation. There have been stressors and smallmouth bass have been able to overcome them or deal with them. But eventually, they get to a point where they cannot deal with them anymore.”*

## NITROGEN AND PHOSPHORUS LEVELS IN THE RIVERS

One factor that parts of the Susquehanna, Monocacy, Potomac, and some other Bay tributaries have in common is high levels of nitrogen and phosphorus.<sup>65</sup> In excessive amounts, these pollutants feed algal blooms the same way fertilizers on land spur plant growth. Algal blooms can trigger not only low-oxygen conditions (as discussed in the previous section) but also spikes in pH levels in the water, which are also stressful to fish.<sup>66</sup>

Data from the U.S. Geological Survey show 12 of 24 sites monitored along the Susquehanna River and its tributaries between 2007 and 2011 had average levels of total phosphorus pollution that were among the worst in the Chesapeake Bay watershed.<sup>67</sup> (“Worst” is defined here as ranking in the top third for levels of nutrient pollution among 65 monitoring sites studied across the Bay watershed). Eleven of the 24 sites in the Susquehanna River and its tributaries had total nitrogen pollution levels that were among the worst, by the same definition.<sup>68</sup> Monitoring sites on the Potomac River and three of its tributaries (the Monocacy River, Antietam Creek, and the Conococheague River) also registered high

### PHOSPHORUS AND NITROGEN POLLUTION LEVELS AT USGS-MONITORED SITES, 2007-2011



Pollution levels are ranked compared to other monitoring sites in the watershed. “Low”=bottom third, “Medium”=middle third, “High”=top third. It is important to note that even some stations classified as “low” have nutrient-related problems (for example, in the upper Potomac). In addition, pollution-reduction strategies in freshwater streams and rivers have traditionally focused on phosphorus, not nitrogen, based on the assumption that algal blooms in fresh water are limited by the availability of phosphorus. CBF examined both nitrogen and phosphorus. There is increasing evidence that, like the Chesapeake Bay, freshwater tributaries would benefit by controls on both nitrogen and phosphorus. Pollution levels in these charts reflect the annual total nitrogen and total phosphorus loads from 2007 to 2011 divided by drainage area, known as “yield.”

levels of nitrogen pollution.<sup>69</sup> And at one of these sites on the Monocacy River, phosphorus levels were also high.<sup>70</sup>

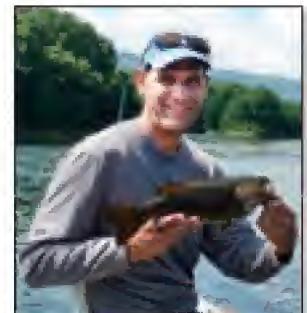
Maryland has officially listed the Monocacy as “impaired” by phosphorus pollution under the federal Clean Water Act.<sup>71</sup> Parts of the Potomac River in Maryland are also “impaired” by phosphorus.<sup>72</sup> Sections of the South Branch of the Potomac River in West Virginia are listed as impaired by excessive amounts of algae,<sup>73</sup> which is an indication of nutrient pollution. Neither the Susquehanna River in Pennsylvania, nor the Shenandoah River in Virginia is listed as impaired for nitrogen or phosphorus pollution. However, some clean-water advocates are suggesting that both should be listed as impaired to speed up pollution reductions.<sup>74</sup>

“We have too much phosphorus and too much nitrogen in our waterways,” said Stephen J. Reeser, District Fisheries Biologist with the Virginia Department of Game and Inland Fisheries.<sup>75</sup> “This nutrient pollution is accelerating algae growth and aquatic macrophyte (plant) growth. And some of our parasites live in hosts that are driven by algae growth. So all of these factors are tied together, and it is not a good thing.”

## PARASITES AND THEIR HOSTS

Excessive amounts of nutrients feed the growth of not only algae and bacteria, but also parasites and their hosts.<sup>76</sup>

Researchers have found a variety of parasites, including trematodes and myxozoans, in adult and juvenile smallmouth bass.<sup>77</sup> Trematodes, parasitic flatworms often called “flukes,” have a complex lifecycle. The parasites often live inside the body of snails before they swim through the water to burrow through the gills or skin of fish.<sup>78</sup> Dr. Blazer and colleagues have also identified three varieties of myxozoan parasites (the name comes from the Greek word for slime) that infect bottom-dwelling worms. The spores of myxozoans then float through the water to attach themselves to smallmouth bass.<sup>79</sup> Some research has suggested that nutrient pollution from wastewater treatment plants and farm runoff can cause myxozoan parasites to multiply.<sup>80</sup> Pollution can also cause the hosts of trem-



**Stephen J. Reeser,**  
District Fisheries Biologist  
with the Virginia  
Department of Game and  
Inland Fisheries

*“We have too much phosphorus and too much nitrogen in our waterways. This nutrient pollution is accelerating algae growth and aquatic macrophyte (plant) growth, which is affecting water quality. And some of our parasites live in hosts that are driven by algae growth. So all these factors are tied together, and it is not a good thing.”*



Parasites are believed to play a key role in causing lesions on smallmouth bass.



**Geoff Smith**

Susquehanna River Biologist  
with the Pennsylvania Fish  
and Boat Commission

*"We find the parasites frequently when we find fish with lesions. In and of itself, the parasite probably wouldn't cause much of the problem. Biologically, it is not beneficial for a parasite to kill its host. But when you throw all these other stressors (including poor water quality) into the mix, then the parasite is fatal."*

#### WHAT IS THE WHIRLING DISEASE?

Whirling disease—caused by a parasite, *Myxobolus cerebralis*—is an often fatal illness in trout, salmon, and other species of fish. Tiny parasites infect young fish, creating nerve damage and skeletal deformation. The infected fish swim in a whirling pattern, making them easy targets for predators.

todes—snails—to multiply rapidly through the creation of “super females” that give birth to legions of parasite-carrying snails.<sup>81</sup>

Why young smallmouth bass have died in large numbers in the Susquehanna River, but not in the Shenandoah or Potomac, is a puzzle that scientists are still trying to solve. Parasites may be a key part of the answer.

According to Dr. Blazer, a possible explanation for the death of young smallmouth in the Susquehanna is the presence in the river of a parasite, *Myxobolus inornatus*, which is similar to the parasite that causes an often fatal illness in trout called the whirling disease (see box below left).<sup>82</sup> A possible host for this parasite has also been found—an invasive species of aquatic Asian worm (*Branchiura sowerbyi*) often found in aquariums and pet stores—although more research is needed to confirm this theory.<sup>83</sup> The parasite’s water-borne spores enter the skin of young smallmouth bass, causing cysts that open up the skin and allow bacteria to enter, triggering deadly infections.<sup>84</sup> It is not yet clear if the parasite or its host are in other Chesapeake rivers.<sup>85</sup>

“We find the parasites frequently when we find fish with lesions,” said Geoff Smith, Susquehanna River Biologist with the Pennsylvania Fish and Boat Commission, who is working with Dr. Blazer on the research.<sup>86</sup> “In and of itself, the parasite probably wouldn’t cause much of the problem. Biologically, it is not beneficial for a parasite to kill its host. But when you throw all these other stressors (including poor water quality) into the mix, then the parasite is fatal.”

## SEXUAL ABNORMALITIES IN SMALLMOUTH BASS

Between 82 percent and 100 percent of male smallmouth bass in the Potomac and Shenandoah Rivers have sexual abnormalities that include eggs growing in their testes, a condition called “intersex,”<sup>87</sup> according to a 2009 paper in *Environmental Toxicology and Chemistry*. Scientists have found intersex with similar frequency in male smallmouth in the Susquehanna River,<sup>88</sup> where between 89 percent and 93 percent of the fish sampled were intersex.<sup>89</sup>

## ENDOCRINE-DISRUPTING CHEMICALS DETECTED IN THE WATER AT SMALLMOUTH BASS NESTING SITES INCLUDE:

- Atrazine (an herbicide used on many farms)
- Dieldrin (an insecticide, now banned)
- Androstanedione (a hormone produced by humans and animals and found in waste)
- 17-beta-Estradiol (a hormone produced by humans and animals and found in waste)
- Tonalide (a synthetic fragrance in cosmetics and detergents)
- 4-Nonylphenol diethoxylate (a chemical used in detergents)

Source: Dana W. Kolpin, Vicki Blazer, and colleagues, “Chemical contaminants in water and sediment near fish nesting sites in the Potomac River basin: Determining potential exposures to smallmouth bass (*Micropterus dolomieu*),” *Science of the Total Environment*, 2013.

Researchers have detected the condition less frequently in smallmouth in rivers across the U.S.<sup>90</sup> Intersex has been linked to lower sperm counts and reduced sperm mobility in smallmouth bass,<sup>91</sup> which could hurt their reproductive capacity. But biologists have not yet seen any firm connections between intersex and population declines in the species, perhaps because each male fish (even when intersex) still produces numerous sperm.<sup>92</sup> The cause of the intersex condition remains unknown.<sup>93</sup> However, a recent study of Potomac River tributaries found 135 different chemicals—including detergents, caffeine, and hormones found in human and farm-animal waste—in the water over smallmouth bass nesting sites.<sup>94</sup> The study also concluded that there is a “significant positive relation between intersex in smallmouth bass and Atrazine,” a commonly used agricultural herbicide.<sup>95</sup> Dr. Blazer’s theory is that intersex is not playing a direct role in the illness or death of the fish, but is a red flag that there is a mixture of chemicals, including known or suspected endocrine-disrupting compounds, in the river that may be causing both the sexual abnormalities and the weakened immune systems of the fish, making them more vulnerable to parasites and bacteria.<sup>96</sup>

## CONCLUSIONS

The problems of smallmouth bass should matter to everyone. Not only are “smallies” a financially valuable sport fish, but they are also an indicator species that is sensitive to pollution. Other fish and animals could also be suffering similar die-offs and illnesses, but we would not necessarily be aware, because an outdoors culture and industry has not been built up around them. So we should listen to what bass are telling us about our ecosystem.

From the troubled health of smallmouth bass, we can recommend some policy actions to both improve the health of the fish and the Chesapeake Bay’s rivers and streams.

- State and local governments should continue the nitrogen and phosphorus pollution reductions required by the Chesapeake Clean Water Blueprint. This means encouraging runoff-control projects and improved fertilizer management on farms; upgrading wastewater treatment plants; rebuilding crumbling urban sewage infrastructure; and reducing urban and suburban stormwater runoff. These actions will restore water quality in rivers and streams and, ultimately, the Chesapeake Bay. Cutting pollutants will help fish health by reducing algal blooms, parasites, and bacterial growth, as well as high pH levels and low-oxygen conditions.
- Pennsylvania should list the Lower Susquehanna River as impaired under the federal Clean Water Act. This will prioritize federal resources to spur greater cross-agency collaborative scientific research to identify the sources and causes of the problems plaguing the smallmouth bass, and create a detailed plan to resolve these problems. In March 2013, the Pennsylvania Department of Environmental Protection announced intensified efforts<sup>97</sup> to expand the study of pollutants in the Susquehanna River basin, and this is a good first step.
- In Virginia, the Commonwealth should ensure that water-quality standards for freshwater rivers and streams (such as the Cowpasture and Shenandoah Rivers) are as protective of recreational uses and fish populations as they are in tidal bodies of water. Evaluation of these standards should take place during the review process that Virginia conducts every three years.

- All of the Chesapeake Bay states should invest more to help farmers fence cattle out of streams. This will reduce the amount of animal waste containing hormones in waterways that could be disrupting fish endocrine and immune systems.
- Local, state, and federal governments and private citizens should prioritize planting and preserving trees and shrubs along streams. These vegetated buffers help filter nitrogen and phosphorus runoff, as well as absorb and degrade herbicides like Atrazine and lawn chemicals.
- Multi-jurisdictional, cross-agency, and academic researchers should continue investigations into endocrine-disrupting chemicals and their potential impact on fish health.

Although the mystery of what is causing smallmouth bass deaths and illnesses is not yet fully solved, scientists know enough to guide policy makers to move ahead with these basic steps. There is no need to wait. The Chesapeake Clean Water Blueprint is a science-based plan to reduce pollution and improve water quality that requires all parties—from suburban governments to businesses and farmers—to do their fair shares. With this cooperative effort, the region is making progress toward cleaner waterways. We owe it to ourselves and our children to finish the job and restore the health of our fish, streams, rivers, and the Chesapeake Bay.

## FISHING FOR ANSWERS IN THE POTOMAC RIVER

Jack Cook has been fishing the Potomac River for 60 years, and he remembers how foul the waters were before the federal Clean Water Act of 1972.

"Back in the 1960s, there was green scum floating on the surface. It stunk and was almost devoid of life," said Cook, 72, former President of the Potomac River Smallmouth Club, a fish conservation group. "The smallmouth population back then was virtually nonexistent."

Cook and many others were overjoyed to see smallmouth bass populations return, starting in the 1970s, as sewage treatment plants were upgraded and the river began to clear up. The number of fish in the river fluctuated in the 1980s and 1990s, but remained relatively healthy, attracting scores of anglers.

Then death and disease swept smallmouth in the South Branch of the Potomac River in 2002 and 2005, the Shenandoah River in 2004 and 2005, and the Monocacy River in 2009.

"Oh, it broke my heart," said Cook, as he fished with a friend recently on the Potomac River southwest of Frederick, Maryland. "It really worries me."

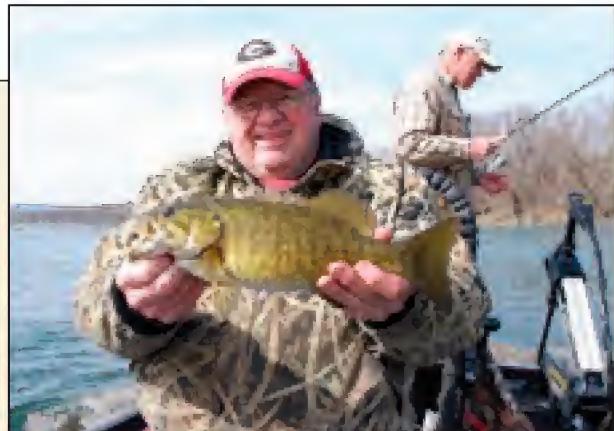
John Mullican, a fisheries manager at Maryland Department of Natural Resources, said that there are no clear population trends down or up for smallmouth in the Potomac River, although reproduction has been down the last five years.

"I don't see an immediate catastrophic issue for the population," Mullican said. "But we are concerned about the mortalities in the Monocacy River, as well as effects endocrine (hormone) disruption may have on smallmouth bass reproduction."

The man who reported the Monocacy River fish kill was Jason Ellis, 36, of Eldersburg, Maryland, a Howard County police officer. Whenever he was off duty, he enjoyed wading down the river with his friends and children.

He gave up fishing the Monocacy, however, on May 23, 2009. On that day, Ellis recalled, he was casting into the forested stream northeast of Frederick, near an old single-lane bridge.

"We really weren't picking up many smallmouth—which was very unusual," Ellis said, as he gazed out on the shady river. "And then, the farther we started walking downstream, the more we started noticing dead fish. There had to be hundreds of dead smallmouth."



Tom Pelton/CBF Staff

*Jack Cook fishing on the Potomac River.*

A follow-up investigation by the Maryland Department of Natural Resources concluded that the fish kill eliminated about 65 percent of the adult smallmouth in the Monocacy.

The Monocacy River flows into the Potomac River, which has improved dramatically since the 1960s, but still has far to go before it is considered healthy. The Potomac received a "D" grade in the most recent (2011) Chesapeake Bay Report Card by the University of Maryland Center for Environmental Science and the National Oceanic and Atmospheric Administration.

Meanwhile, Cook and other anglers continue to fish.

On a recent morning, Cook and a friend, Bill Pearl, cruised in a shallow-bottomed jet boat down the Potomac, weaving between rocks until they found a good place to target smallmouth. Pearl and Cook cast lures that looked like black rubbery squids into an eddy behind a large boulder. They paused to allow the lures to sink to the bottom, then slowly reeled them in.

"Pound for pound, smallmouth bass are the hardest fighting fish there is," Cook said. "Anyone can catch those dumb old largemouth bass. But we feel it takes some skill to catch smallmouth."

He paused for a moment, then smiled broadly as he glanced at his friend. "Well, Bill's got no pride," Cook said, joking. "He'll fish for largemouth."

He grew more serious, however, when he thought about future generations not being able to enjoy the sport that has run like a warm current through his life.

"I need to have a nice, healthy river," Cook said, "so my grandkids can catch fish."

## **END NOTES**

### **EXECUTIVE SUMMARY**

- <sup>1</sup> V.S. Blazer, L.R. Iwanowicz, C.E. Starliper and D.D. Iwanowicz, "Mortality of Centrarchid Fishes in the Potomac Drainage: Survey Results and Overview of Potential Contributing Factors," *Journal of Aquatic Animal Health*, 22:190-218, 2010.
- <sup>2</sup> Ibid. and Pennsylvania Fish and Boat Commission, "Factors Affecting Smallmouth Bass Populations in the Susquehanna River," December 11, 2012.
- <sup>3</sup> Pennsylvania Fish and Boat Commission, "Factors Affecting Smallmouth Bass Populations in the Susquehanna River," December 11, 2012.
- <sup>4</sup> Pennsylvania Fish and Boat Commission, Catch and Release Bass Regulations for 2012.
- <sup>5</sup> Interview on January 9, 2013, with Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey.
- <sup>6</sup> Blazer, "Mortality of Centrarchid Fishes."
- <sup>7</sup> Pennsylvania Fish and Boat Commission, "Factors Affecting Smallmouth Bass Populations in the Susquehanna River," December 11, 2012.
- <sup>8</sup> Interview on January 31, 2013, with John Mullican, Western Region, District II Manager, Inland Fisheries Division of the Maryland Department of Natural Resources.
- <sup>9</sup> Blazer, "Mortality of Centrarchid Fishes."
- <sup>10</sup> The five biologists interviewed by CBF were Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey; John Mullican, Western Region, District II Manager, Inland Fisheries Division of the Maryland Department of Natural Resources; Stephen Reeser, District Fisheries Biologist with the Virginia Department of Game and Inland Fisheries; Jim Hedrick, District Fisheries Biologist with the West Virginia Division of Natural Resources; and Geoff Smith, Susquehanna River Biologist with the Pennsylvania Fish and Boat Commission.
- <sup>11</sup> Sources for economic impact numbers: U.S. Fish and Wildlife Service's 2011 National Survey of Fishing, Hunting- and Wildlife-Associated Recreation; American Sportfishing Association's "Sportfishing in America, 2013;" and State wildlife management agencies in Maryland, Virginia, and Pennsylvania; with assistance from Dr. Douglas W. Lipton, Associate Professor and Program Leader of Sea Grant Programs at the University of Maryland College of Agriculture and Natural Resources. Note: sales figures are for 2011 (the most recent available data) and take into account a multiplier or "ripple effect" in the economy.
- <sup>12</sup> U.S. Geological Survey, Chesapeake Bay Watershed 5-year Short Term Phosphorus Yields, 2007 to 2001. Information available on Chesapeake Bay Program website: [www.chesapeakebay.net/maps/map/chesapeake\\_bay\\_watershed\\_5\\_year\\_short\\_term\\_phosphorus\\_yields](http://www.chesapeakebay.net/maps/map/chesapeake_bay_watershed_5_year_short_term_phosphorus_yields). Nitrogen yield data available at: [www.chesapeakebay.net/maps/map/chesapeake\\_bay\\_watershed\\_5\\_year\\_short\\_term\\_nitrogen\\_yields](http://www.chesapeakebay.net/maps/map/chesapeake_bay_watershed_5_year_short_term_nitrogen_yields).
- <sup>13</sup> Ibid.
- <sup>14</sup> Dr. Vicki Blazer, "Skin Lesions and Mortality of Fishes in the Chesapeake Bay Watershed," October, 2012.

<sup>15</sup> U.S. Geological Survey report, “Water-Quality Monitoring in Response to Young-of-the-Year Smallmouth Bass (*Micropterus dolomieu*) Mortality in the Susquehanna River and Major Tributaries, Pennsylvania,” 2008.

<sup>16</sup> H.L. Walsh, V.S. Blazer, L.R. Iwanowicz, G. Smith, “A redescription of *Myxobolus inornatus* from young-of-the-year smallmouth bass (*Micropterus dolomieu*),” *Journal of Parasitology*. December 2012;98(6):1236-42. doi: 10.1645/GE-3081.1. Epub 2012 Jun 4.

<sup>17</sup> Interview on January 9, 2013, with Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey. Dr. Blazer and colleagues have identified an Asian benthic worm, *Branchiura sowerbyi*, as a potential host in the Susquehanna River for the *Myxobolus inornatus* parasite, although more research is needed to confirm this.

<sup>18</sup> Chesapeake Bay Foundation, “Debunking the ‘Job Killer’ Myth: How Pollution Limits Encourage Jobs in the Chesapeake Bay Region,” January 2012. [www.cbf.org/document.doc?id=1023](http://www.cbf.org/document.doc?id=1023).

#### **DESCRIPTION AND HISTORY OF SMALLMOUTH BASS**

<sup>19</sup> Interview on February 25, 2013, with Jack Cook, former President of the Potomac River Smallmouth Club.

<sup>20</sup> Maryland Department of Natural Resources, “Fish Facts” fact sheet. [www.dnr.state.md.us/fisheries/fishfacts/smallmouthbass.asp](http://www.dnr.state.md.us/fisheries/fishfacts/smallmouthbass.asp).

<sup>21</sup> Pennsylvania Fish and Boat Commission, Smallmouth Bass. [www.fishandboat.com/pafish/fishhtms/chap22.htm](http://www.fishandboat.com/pafish/fishhtms/chap22.htm).

<sup>22</sup> Pennsylvania Fish and Boat Commission, Know Your Bass. [www.fish.state.pa.us/anglerboater/2003/ja03angler/knowbass.pdf](http://www.fish.state.pa.us/anglerboater/2003/ja03angler/knowbass.pdf).

<sup>23</sup> Pennsylvania Fish and Boat Commission, Smallmouth Bass. [www.fishandboat.com/pafish/fishhtms/chap22.htm](http://www.fishandboat.com/pafish/fishhtms/chap22.htm).

<sup>24</sup> Stephen J. Reeser, District Fisheries Biologist, Virginia Department of Game and Inland Fisheries, “Shenandoah River Fish Population Assessment Following Fish Kills 2004-2007,” March 25, 2008.

<sup>25</sup> Interview on February 25, 2013, with Jack Cook, former President of the Potomac River Smallmouth Club.

<sup>26</sup> Smithsonian Environmental Research Center, NEMESIS online database of introduced species in the Chesapeake Bay region. <http://invasions.si.edu/nemesis/>.

<sup>27</sup> Ibid.

<sup>28</sup> All stocking dates from NEMESIS database above.

#### **ECONOMIC AND BIOLOGICAL SIGNIFICANCE**

<sup>29</sup> Sources for economic impact numbers: U.S. Fish and Wildlife Service’s 2011 National Survey of Fishing, Hunting- and Wildlife-Associated Recreation; American Sportfishing Association’s Sportfishing in America, 2013; and state wildlife management agencies in Maryland, Virginia, and Pennsylvania; with assistance from Dr. Douglas W. Lipton, Associate Professor and Program Leader of Sea Grant Programs at the University of Maryland College of Agriculture and Natural Resources. Note: sales figures are for 2011 (the most recent

available data) and take into account a multiplier or “ripple effect” in the economy.

<sup>30</sup> Maria Papadakis, “The Economic Impact of the 2005 Shenandoah River Fish Kill: A Preliminary Economic Assessment.” James Madison University, 2006.

<sup>31</sup> Interview on February 25, 2013, with Jack Cook, former President of the Potomac River Small-mouth Club.

<sup>32</sup> Interview on January 17, 2013, with John Arway, Executive Director of the Pennsylvania Fish and Boat Commission.

<sup>33</sup> Interview on January 31, 2013, with John Mullican, Western Region, District II Manager, Inland Fisheries Division of the Maryland Department of Natural Resources.

<sup>34</sup> Ibid.

#### **CHRONOLOGY OF MORTALITY AND DISEASE**

<sup>35</sup> V.S. Blazer, L.R. Iwanowicz, C.E. Starliper, and D.D. Iwanowicz, “Mortality of Centrarchid Fishes in the Potomac Drainage: Survey Results and Overview of Potential Contributing Factors,” *Journal of Aquatic Animal Health*, 2010, p. 191.

<sup>36</sup> Ibid., p.190.

<sup>37</sup> Interview on February 26, 2013, with Jim Hedrick, District Fisheries Biologist with the West Virginia Division of Natural Resources.

<sup>38</sup> V.S. Blazer, L.R. Iwanowicz, C.E. Starliper, and D.D. Iwanowicz, “Mortality of Centrarchid Fishes in the Potomac Drainage: Survey Results and Overview of Potential Contributing Factors,” *Journal of Aquatic Animal Health*, 2010, p.192.

<sup>39</sup> Ibid.

<sup>40</sup> Ibid.

<sup>41</sup> Ibid.

<sup>42</sup> Ibid.

<sup>43</sup> Ibid.

<sup>44</sup> Pennsylvania Fish and Boat Commission, “Factors Affecting Smallmouth Bass Populations in the Susquehanna River,” December 11, 2012.

<sup>45</sup> E-mail on March 19, 2013, from Geoff Smith, Susquehanna River Biologist with the Pennsylvania Fish and Boat Commission.

<sup>46</sup> Ibid.

<sup>47</sup> Pennsylvania Fish and Boat Commission, “Factors Affecting Smallmouth Bass Populations in the Susquehanna River,” December 11, 2012. The 80 percent decline in catch rate figure comes from chart, “Catch per unit of effort (CPUE) of adult smallmouth bass *Micropterus dolomieu* at the middle Susquehanna River (Sunbury to York Haven Dam); 1990- present.

<sup>48</sup> Interview on January 17, 2013, with John Arway, Executive Director of the Pennsylvania Fish and Boat Commission.

<sup>49</sup> Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey; John Mullican, Western Region, District II Manager, Inland Fisheries Division of the Maryland Department of Natural Resources; Stephen Reeser, District Fisheries Biologist with the Virginia Department of Game

and Inland Fisheries; and Geoff Smith, Susquehanna River Biologist with the Pennsylvania Fish and Boat Commission.

<sup>50</sup> Interview on February 26, 2013, with Jim Hedrick, District Fisheries Biologist with the West Virginia Division of Natural Resources. Interview on January 28, 2013, with Stephen Reeser, District Fisheries Biologist with the Virginia Department of Game and Inland Fisheries. Interview with John Mullican, Western Region, District II Manager, Inland Fisheries Division of the Maryland Department of Natural Resources.

<sup>51</sup> Interview with Stephen Reeser, District Fisheries Biologist with the Virginia Department of Game and Inland Fisheries.

#### **THEORIES ABOUT THE CAUSES OF FISH DISEASE AND MORTALITY**

<sup>52</sup> Interview on January 9, 2013, with Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey.

<sup>53</sup> March 22, 2013, e-mail from Geoff Smith, Susquehanna River Biologist with the Pennsylvania Fish and Boat Commission.

<sup>54</sup> January 9, 2013, interview with Dr. Vicki Blazer; and Blazer paper, “Skin Lesions and Mortality of Fishes in the Chesapeake Bay Watershed,” U.S. Geological Survey, October 2012.

<sup>55</sup> V.S. Blazer, L.R. Iwanowicz, C.E. Starliper and D.D. Iwanowicz, “Mortality of Centrarchid Fishes in the Potomac River Drainage: Survey Results and Overview of Potential Contributing Factors,” *Journal of Aquatic Animal Health*, 22:190-218, 2010, p. 205.

<sup>56</sup> Ibid. Also, e-mail from Dr. Vicki Blazer on March 10, 2013.

<sup>57</sup> Interview on January 9, 2013, with Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey.

<sup>58</sup> Interview on January 17, 2013, with John Arway, Executive Director of the Pennsylvania Fish and Boat Commission. Pennsylvania Fish and Boat Commission, “Factors Affecting Smallmouth Bass Populations in the Susquehanna River,” December 11, 2012.

<sup>59</sup> U.S. Geological Survey report, “Water-Quality Monitoring in Response to Young-of-the-Year Smallmouth Bass (*Micropterus dolomieu*) Mortality in the Susquehanna River and Major Tributaries, Pennsylvania,” 2008.

<sup>60</sup> Ibid.

<sup>61</sup> American Water Resources Association, Pennsylvania Chapter, “The Susquehanna River and Smallmouth Bass—Disease and Environmental Factors, 2012.” [http://state.awra.org/pennsylvania/basin\\_reports/archives/SusquehannaBasinReportSpring2012.pdf](http://state.awra.org/pennsylvania/basin_reports/archives/SusquehannaBasinReportSpring2012.pdf).

<sup>62</sup> Interview on January 9, 2013, with Dr. Vicki Blazer, Research Fisheries Biologist with the U.S. Geological Survey. Interview on January 28, 2013, with Stephen Reeser, District Fisheries Biologist with the Virginia Department of Game and Inland Fisheries.

<sup>63</sup> Interview on January 28, 2013, with Stephen Reeser, District Fisheries Biologist with the Virginia Department of Game and Inland Fisheries.

<sup>64</sup> Interview on February 26, 2013, with Jim Hedrick, District Fisheries Biologist with the West Virginia Division of Natural Resources.

## **NITROGEN AND PHOSPHORUS LEVELS IN THE RIVERS**

<sup>65</sup> U.S. Geological Survey, “Chesapeake Bay Watershed 5-year Short Term Phosphorus Yields, 2007 to 2011.” Information available on Chesapeake Bay Program website: [www.chesapeakebay.net/maps/map/chesapeake\\_bay\\_watershed\\_5\\_year\\_short\\_term\\_phosphorus\\_yields](http://www.chesapeakebay.net/maps/map/chesapeake_bay_watershed_5_year_short_term_phosphorus_yields). Nitrogen yield data available at: [www.chesapeakebay.net/maps/map/chesapeake\\_bay\\_watershed\\_5\\_year\\_short\\_term\\_nitrogen\\_yields](http://www.chesapeakebay.net/maps/map/chesapeake_bay_watershed_5_year_short_term_nitrogen_yields).

<sup>66</sup> Pennsylvania Fish and Boat Commission, “Factors Affecting Smallmouth Bass Populations in the Susquehanna River,” December 11, 2012.

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**The Chesapeake Bay's 64,000-square-mile watershed covers parts of six states and is home to more than 17 million people.**